EVs-at-RISC: A Secure and Resilient Smart Charge Management Control System Architecture for Electric Vehicles At-Scale

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2022 DoE Vehicle Technologies Office Annual Merit Review
Project ID: ELT265

Overview_

Timeline

- Start date: October 1, 2020
- End date: December 31, 2024
- Percent complete: 40%

Budget

- Total Project Funding: $7.05M
  - DoE share: $4.76M
  - Cost share: $2.28M
- FY22: $2.2M

Barriers

- Utilities and grid operators lack a standard interface to manage and interact with EV, EVSE, and DER assets at the grid edge
- Non-interoperability (heterogeneity of management interface/protocol) limits Smart Charge Management use cases
- Non-standardization of control/communications interfaces expands attack surface, threatens grid cybersecurity and resilience

Partners

- DTE Energy
- NextEnergy
- RunSafe Security
- RedStone Tech. Integration
- Idaho National Laboratory
- Oak Ridge National Lab
- American Center for Mobility
- Utah State University

Relevance_

- Heterogeneity between EVSE and EV charging systems limits interoperability, increases grid integration cost, expands attack surface, and prevents coordinated asset optimization for Smart Charge Management (SCM) use cases
- SCM requires a standard interface to deploy software to interact with and manage EV charging infrastructure
- Power communications infrastructure lacks basic capabilities for encryption, authentication

➢ Lack of robust cybersecurity TTPs in distribution networks magnify threats from malicious/compromised EVs, EVSE

Objectives:

- Research and develop an open-source, utility Smart Charge Management system based on existing open standards
- Research and develop secure interoperability solutions for distribution networks that:

➢ Provide a standardized, extensible, and scalable interface to interact with legacy, modern, and future energy OT assets

➢ Reduce the cost, complexity, and cybersecurity risks of EV, EVSE, DER grid integration

➢ Enable greater operational flexibility and situational awareness at the grid edge

➢ Provide long-term protocol-, vendor-, and hardware-independence and agnosticism

Milestones_

Any proposed future work is subject to change based on funding levels.

AS OF: April 10, 2022	FY21				FY22				FY23				FY24				FY25
	Q1	Q2	Q3	Q4	Q1	Q2	Q3	Q4	Q1	Q2	Q3	Q4	Q1	Q2	Q3	Q4	Q1
SCM requirements specification completed																	
Model development and implementation completed																	
System architecture development completed																	
Data model specification completed																	
Demonstrate OpenFMB implementation completed (GO/NO-GO)																	
Integrate system with laboratory hardware																	
Security microservice applications completed																	
Charge control microservice applications completed																	
Grid service microservice applications completed																	
Laboratory demonstration of project use cases completed (GO/NO-GO)																	
Demonstrate interoperability use case																	
Demonstrate smart charging use case																	
Demonstrate cybersecurity use case																	
Demonstrate grid service capabilities																	
Demonstrate system achievement of project goals (GO/NO-GO)																	
Performance report completed																	
Reference architecture specification completed																	
Best practices report completed																	
Distribution of open-source deliverables completed																	

	Complete
	In progress
	Planned

Approach_

1. Standardize a control approach and infrastructure for interacting with any EV, EVSE/DER, and OT device

- Adapt OT protocols to a mature, widely adopted semantic information model
- Perform protocol adaptation at the grid edge; minimize implicit trust boundaries
- Eliminate client-server architectures in favor of publish-subscribe (scalability, reliability, cost)

2. Extend this infrastructure with an interoperable middleware layer and edge computing platform

- Develop control profiles for EV, EVSE/DER, and aggregate operators
- Flexibly deploy SCM, grid service, and cyber policies & applications to any grid edge OT asset or interface
- Support a hybrid software/hardware approach to eliminate dependence on vendor cooperation
- Heavily leverage the open-source ecosystem and COTS (cost, accessibility, flexibility, long-term benefit)

By applying emerging technologies + proven networking concepts, we've created scalable, non-invasive, secure, and affordable solutions for wide-scale interoperability, SCM, and grid services with any EV & EVSE

Technical Accomplishments and Progress (New)
Milestone 2: Model development and implementation completed_

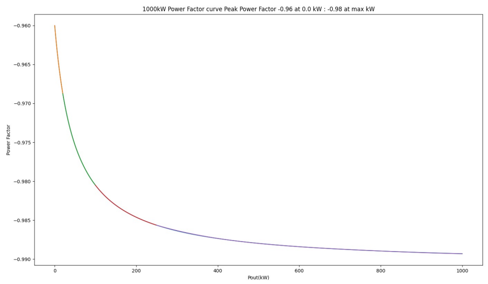
- We extended Caldera to add DCFC, BEV, DWPT models
- ➢ Higher power DC XFC models up to 3MW
- ➢ Higher capacity EV models up to 1MWh

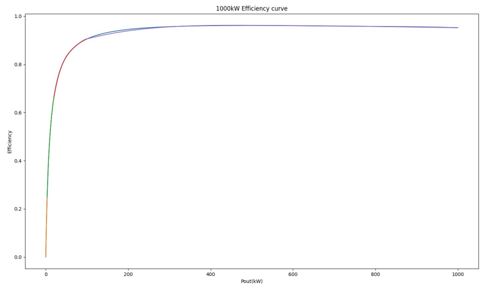
Charger Name	dc Power Limit (kW)	dc Current Limit (Amps)
dcxfc_500	500	2500
dcxfc_1000	1000	5000
dcxfc_2000	2000	10000
dcxfc_3000	3000	15000

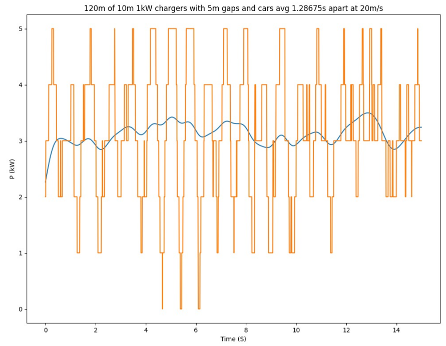
EV Name	watt hr / mile	Usable Battery Size (kWh)
bev50kWh	500	50
bev100kWh	1000	100
bev200kWh	2000	200
bev300kWh	3000	300
bev400kWh	4000	400
bev600kWh	6000	600
bev800kWh	8000	800
bev1MWh	10000	1000

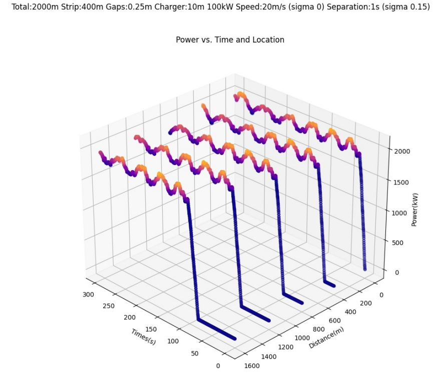
- We extended OpenDSS ecosystem to support PV, BESS modeling and injection in OpenDSS simulations

- We validated model implementation across 9 months of use case T&E
- ➢ Began SCM control strategy development









Technical Accomplishments and Progress (New)
Milestone 3: System architecture development completed_

- Detailed system architecture, software and hardware specifications complete 06/22
- Initial system development and integration complete 09/22

- First industrial-grade laboratory integration complete 10/22-11/22
- Details shown in slides 9, 10

- Received widespread approval from DoE offices, utility partner, DSO & ISO collaborators, test sites, vendors, and OEMs
- Achieved flexible deployment and performance efficiency in both airgapped and cloud-integrated operational test environments

➢ *Further proprietary details redacted; please reach out for more information*

Technical Accomplishments and Progress (New)
Milestone 4: Data model specification completed

- UCA/OpenFMB global task force lead: EVSE module design

- Using IEC61850-90-8, we developed (standardized) the:

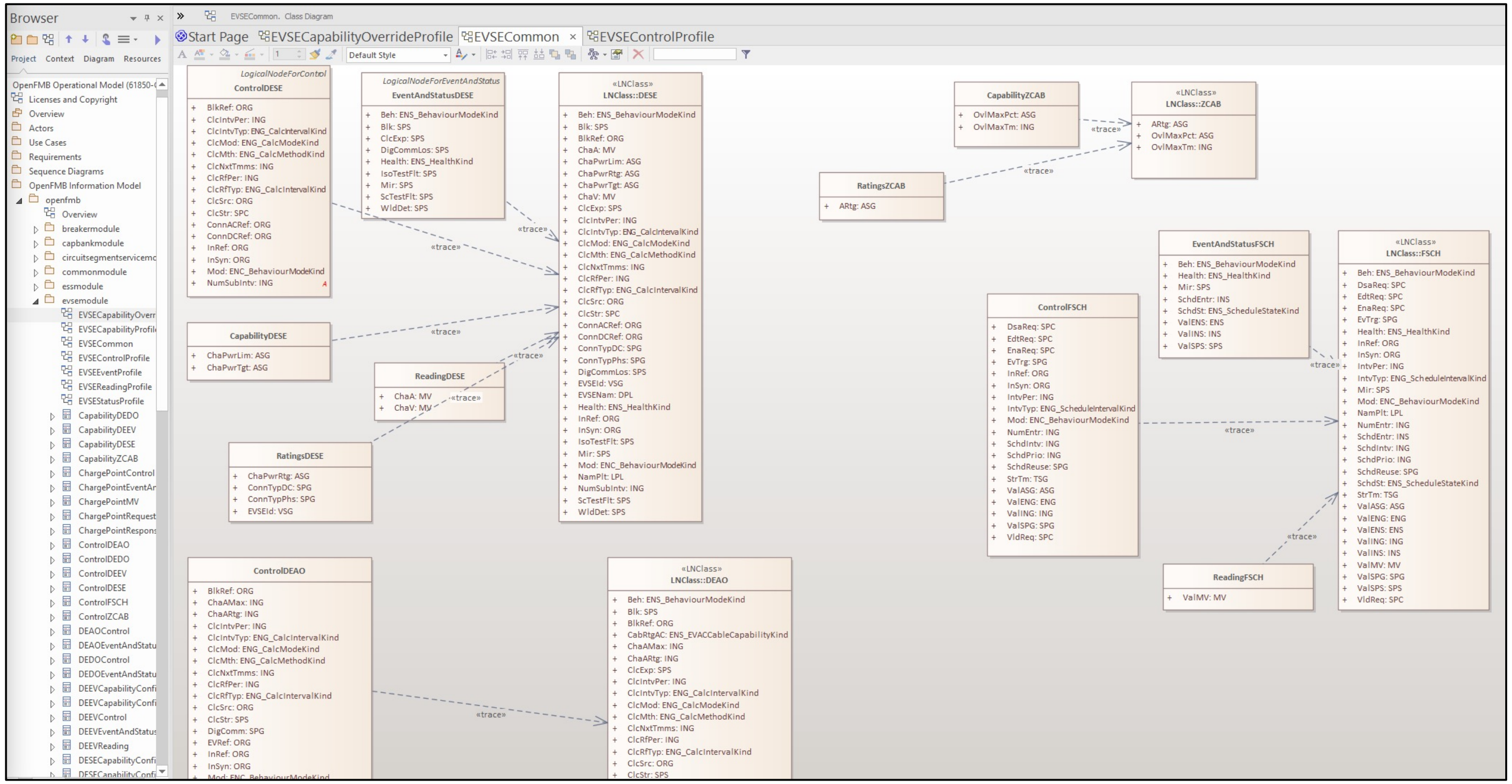
➢ EVSE common data model

➢ Control profile

➢ Event profile

➢ Reading profile

➢ Status profile

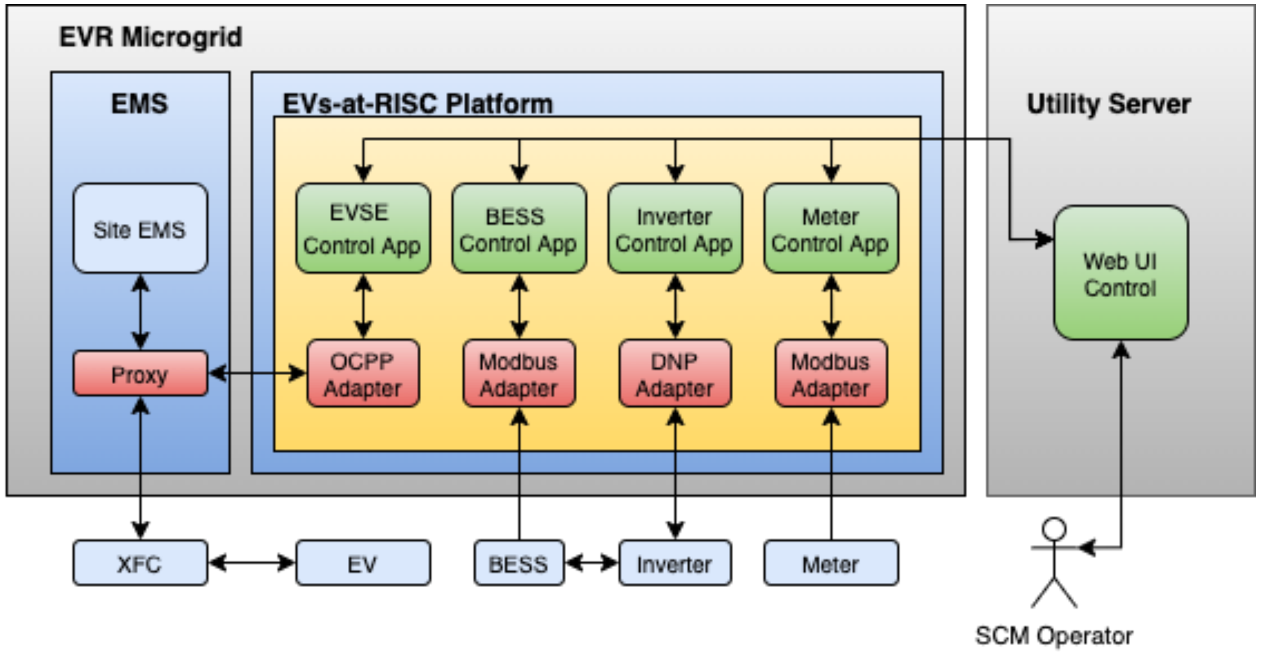


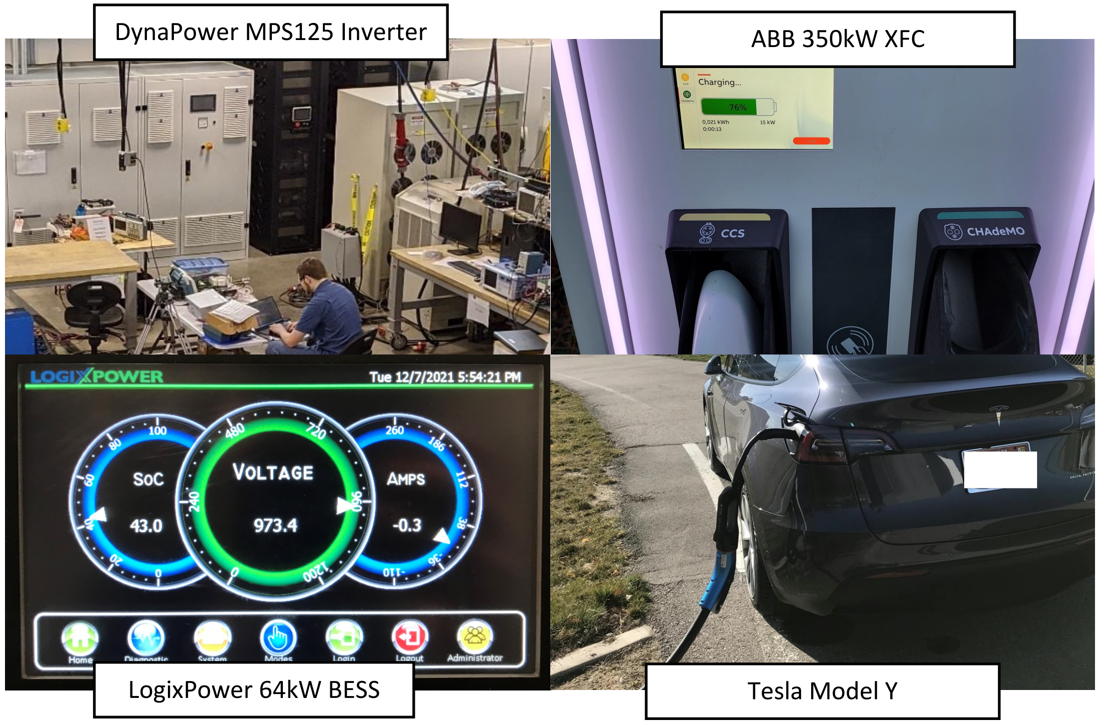
- Weekly effort with collaboration and support from UCA, SEL, Duke, ABB, and others

Technical Accomplishments and Progress (New)
Milestone A (G/NG): Demonstrate OpenFMB implementation completed

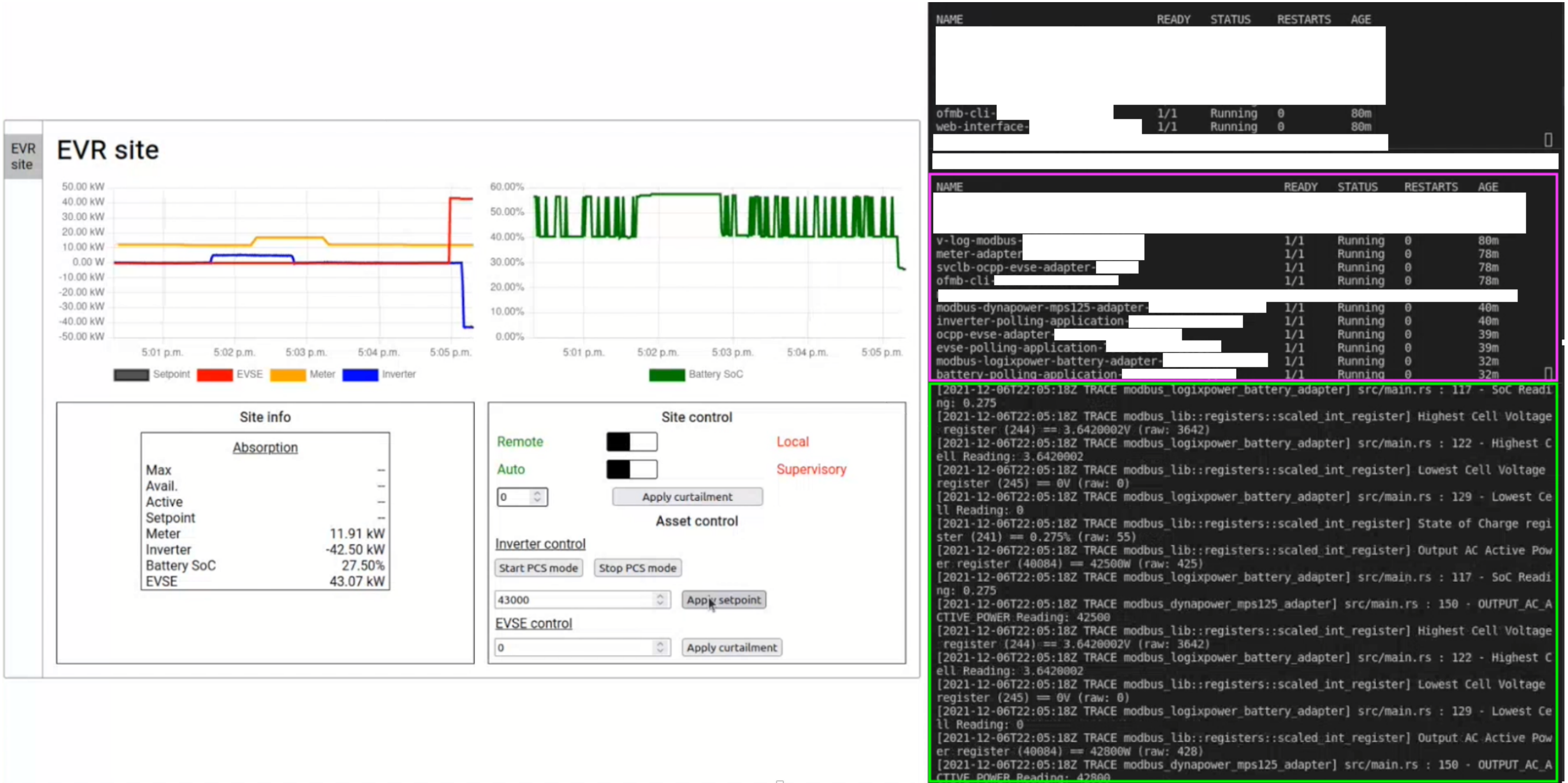
- Successful TRL-5 demonstration in laboratory test environment

➢ Interoperable curtailment of microgrid assets using EVs-at-RISC OpenFMB implementation





Technical Accomplishments and Progress (New)
Milestone A (G/NG): Demonstrate OpenFMB implementation completed



Response to 2021 Reviewer Comments_

- *'There are a number of existing standards being worked on to develop communications protocols to enable interoperable charging systems. Instead of working within those existing activities, the approach used in this project seems to be to "develop an open-source, open standards-based utility Smart Charge Management system." No alternative approaches seem to have been considered'*
- **Response**: This is incorrect. EVs-at-RISC achieves interoperability by leveraging and extending the Open Field Message Bus information model, which is standardized by a worldwide consortium of utilities, OEMs, and other key players and is based on IEC 61850 and CIM. Most existing interoperability efforts rely on ubiquitous adoption of specific protocols (ex. OpenADR) – which is not interoperability at all! Instead, this approach will produce interoperability solutions that are protocol agnostic, and which provide sustainable interoperability with legacy, current, and any future communications technology by unifying these fractured efforts and interoperability projects using OpenFMB.

- *'The reviewer indicated that there are a number of existing standards being worked on ... the existing standard organizations should have been brought into the discussion along with members of the industries that support EV charging'*
- **Response**: We agree; in the last year, we have built out a global community of stakeholders (including utilities, regulators, standards organizations, OEMs, and others) whom we engage with regularly in standing weekly and/or monthly meetings to ensure long-term alignment of EVs-at-RISC efforts with industry growth, market development, and technology evolution.

- *'One concern here is that one task is labeled "demonstrate cybersecurity use case"; cybersecurity should be considered for every aspect of the project and not confined to a single use case'*
- **Response**: We agree; our team has been developing zero-trust architectures for 30 years. Our approach to cybersecurity is holistic and the EVs-at-RISC solution implements a zero-trust architecture and defense-in-depth approach which drives all aspects of development and systems integration. This milestone simply puts our holistic security architecture to the test through live red team testing and use case demonstrations which will align with the key threats relevant to the energy sector during the Demonstration Phase (2023-2024).

Collaborations_

TEAM LIBERAS – a diverse mix of stakeholders necessary to design and develop a system aligned with real-world customer requirements and deployment scenarios

- **Utility partner**: DTE Energy
- Role: key customer/stakeholder input; test & demonstration site operator; representative commercialization & deployment partner

- **National lab partners**: INL, ORNL
- INL role: Modeling and simulation extending Caldera; security analysis & red team
- ORNL role: DWPT EVSE integration and T&E partner

- **University partner**: Utah State University (USU)
- Role: SCM control strategy design, development, T&E

- **Industry partners**: RunSafe Security, RedStone Technology Integration (RTI)
- RunSafe role: Run time protection software vendor
- RTI role: Systems integration strategy & architecture design

- **Test sites**: American Center for Mobility, NextEnergy
- Role: Providing access to representative real-world test sites for pre-production deployment, T&E

Remaining Challenges and Barriers_

- PKI sharing and/or federation across EVSE/V2G ecosystem stakeholders (DSO, CPO, eMSP, etc.)
- Increasing scalability of cost efficiency, performance, and deployment ease across massive power distribution networks
- Designing SCM control strategies and flexible contracts which address the needs of DSO & ISO
- Transitioning TRL-6 solution to TRL-7 wide-scale demonstration environment

Any proposed future work is subject to change based on funding levels.

Proposed Future Research_

FY22 Activities

- Complete development of software interfaces for distribution systems, EVs, EVSE, and DER
- Develop middleware applications for SCM and grid services. Design charge control strategies.
- Demonstrate mature implementations of SCM capabilities in laboratory and fielded R&D environments.

FY23 Activities

- EVs-at-RISC systems integration and TRL-6/7 operational deployment at multiple field sites
- Wide-scale system demonstration of:
  - ➢ SCM capabilities across 50+ EVSE at multiple remote sites in Michigan & Utah
  - ➢ Grid services enrollment and execution by EVSE, DER, and aggregators
  - ➢ Power and network systems resilience and recovery; cyber threat identification, response, and recovery

Any proposed future work is subject to change based on funding levels.

Summary_

EVs-at-RISC will produce an open-source, open standards-based SCM system for distribution networks with support for interoperable, secure management and grid integration of EVs, EVSE, and DER

- Develop an extensible architecture for secure, interoperable control of heterogeneous distribution assets
- Standardize a software deployment architecture for distribution networks – develop and deploy protocol-agnostic software applications that can interact with any distribution asset
- Realize wide-scale capabilities to use EV, EVSE, DER for SCM and grid support services
- Mitigate cybersecurity risks from legacy systems, compromised EVSE/DER, and scaled OT-IT integrations

Current state: TRL-6 Smart Charge Management capabilities demonstrated in a pre-production utility environment

- Base system deployment to cyberphysical test environments – ongoing, initial deployments complete
- SCM & grid service control strategy evaluation – scheduled for 07/22
- Cyber assessments and red team evaluation – scheduled for 09/22
- Deployment to cyberphysical demonstration environments – scheduled for 04/23

Any proposed future work is subject to change based on funding levels.